[Second Edition.

PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in and relating to Gas Filled Electric Discharge Devices and Circuits therefor.

We, THE BRITISH THOMSON-HOUSTON COMPANY, LIMITED, a British Company having its registered office at Crown House, Aldwych, London, W.C.2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

Our invention relates to gaseous electric discharge devices of the low pressure type having thermionic electrodes and an operating atmosphere comprising a gas and a metallic vapour. Still more particularly it relates to an improved construction of such gaseous electric discharge lamps and to an improved and simplified method of operating the same, whereby the useful operating life is substantially increased.

Hitherto the use of low pressure gaseous discharge devices as light sources has been hampered by the large amount of auxiliary equipment necessary for their operation. This necessity arises, first, from the fact that the voltage required to initiate the discharge is generally much greater than the normal operating voltage and, secondly, from the fact that unless the thermionic cathodes are preheated for a definite length of time they are not only damaged themselves by current bombardment, but in addition the envelope walls are blackened by material sputtered from them. This bombardment is particularly prevalent during the starting operation before the cathodes have reached proper operating temperature. It has thus been necessary to provide a mechanism to delay the application of the voltage between the main electrodes while a preliminary heating current flows through the thermionic cathodes, and then to provide a high starting voltage itself. Such mechanisms are not only objectionable because they add to the overall cost, but also because they tend to burn out or get out of order for other reasons. Further, the operation of the switching mechanisms tends to produce transient voltages which damage the lamp and the auxiliary equipment. All of these factors affect the reliability of the lighting unit as a whole. We have found, however, that by proper design of the lamp and attendant supply circuit in accordance with the invention, it is possible to construct a lamp which is capable of withstanding the heavy bombardment during the starting period without the deleterious effects of sputtering and blackening and which, at the same time, starts more readily. With such a design, it becomes possible to eliminate much of this cumbersome auxiliary equipment now necessary with discharge lamps.

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It is accordingly an object of the invention to provide a low pressure gaseous discharge lamp capable of withstanding the effects of starting without undue sputtering or vaporizing of the cathodes whereby preheating of the cathodes is made unnecessary.

It is a further object of the invention to eliminate the need for the greater part of the auxiliary control mechanism now necessary with lamps of the type herein described.

Still another object of the invention is to provide a more simple and inexpensive lighting unit which is more reliable in operation and economical in manufacture.

The invention consists in a low pressure gaseous electric discharge device comprising an envelope containing at least one pair of operating electrodes, at least one of which is activated, and a gaseous atmosphere, the activated electrode having a ratio of effective electron emitting surface in square centimeters to heat capacity in calories per gram not less than 176 to permit its being heated to electron emissive temperature before substantial deterioration by sputtering can occur, means for applying an electrical potential to the device whereby an operation potential is applied between the electrodes and whereby the activated electrode is simultaneously heated, the activated electrode being heated at a rate sufficient to cause it to reach electron emissive temperature within a time insufficient to permit substantial sputtering thereof by the discharge current.

Further and other objects of the invention will appear from the following de-

tailed description and from the accompanying drawings in which Fig. 1 represents a gaseous discharge lamp of the type here involved and an improved circuit for operating the same, while Fig. 2 illustrates in more detail an improved cathode construction for the same. Fig. 3 represents an enlarged section of the winding of our cathode.

Referring to Fig. 1, the lamp 1 may be of the fluorescent type now prevalent in the art, for example, it may incorporate an envelope 2 having a fluorescent coating 3 on the inside surface thereof and a quantity of vapourizable metal 4, such as mercury, sufficient to produce vapour pressures up to about twenty microns. A quantity of starting gas such as argon or neon or any of the rare gases may be provided at the pressures hereinafter specified. The lamp also includes an activated cathode 5 and a pair of anodes 6, preferably of carbon, the anodes being separated by an insulating baffle 7. The lamp may be energized by a current supply circuit indicated generally by the numeral 8, which will be described more in detail below.

Ordinarily, unless such a lamp is operated in a circuit which insures preheating of the cathode before the main discharge is struck, the useful life is extremely short. This is due to the fact that before the cathode reaches proper operating temperature, it emits an insufficient number of electrons to materially lower the potential gradient in the tube. If full voltage is applied between operating electrodes in this condition, a very high potential gradient exists at the cathode with the result that it may be subjected to very heavy positive ion bombardment. Such positive ion bombardment destroys the coating and sputters part of it and some of the cathode metal itself to the envelope wall where it collects as a black coating. This coating considerably impairs not only the lighting efficiency, but also the appearance of the lamp. If, however, the cathode has reached proper electron emitting temperature before the voltage is applied, the high potential gradient at the cathode does not arise and consequently the positive ions do not acquire sufficient energy to materially damage the cathode surface.

Extensive tests have shown that this sputtering and blackening process is largely confined to the starting period. This is readily understandable in view of what has already been said about the heating of the cathode and its susceptibility to bombardment when cold. We have found that the primary factor in determining the amount of sputtering and blackening during this warming-up period is the rapidity with which the cathode heats up. Thus, if its heat capacity is very small, the cathode will warm up to full emission temperature before substantial sputtering occurs. We find, however, that by choosing a form which reduces the mass and at the same time provides a large emitting surface, it is possible to measurably decrease the heat capacity and, consequently, the heating time. Thus, in one case we succeeded in obtaining measurably improved results by decreasing the cathode wires to one-quarter the former mass per unit length and by providing multiple winding of this wire to supply the necessary area. For example, in a standard 85 watt 0.9 ampere R.F. lamp (rectifying fluorescent) the new cathode took the form of 18 double turns with inside diameter equal to 0.060″ (60 mil) using coiled coil wire comprising tungsten wire 0.006″ in diameter overwound with 0.0015″ tungsten wire at about 400 turns per inch. These dimensions are about the largest allowable if the advantage of the invention are to be realized. The resulting cathode has considerably less mass than the cathodes hitherto used and still has an equivalent emitting surface area. Because of this decreased mass, it will rise to full operating temperature much more rapidly than do the constructions hitherto known. For larger currents or for still faster action, an even smaller filament wire (for example, a coiled coil of 0.004″ wire overwound with 0.0015″ wire) could be used and the necessary increase in area obtained by placing more than two windings in multiple. The windings must, however, be positioned close together, otherwise they will not share the current burden properly. It will be thus apparent that by using multiple windings of fine wire, the ratio of electron emitting area to mass will be greatly increased with an attendant considerable decrease in the heat capacity for the same effective emitting area.

The Fig. 2 shows the cathode of Fig. 1 in greater detail and is exemplary of the cathode construction just described. The cathode coil 9 comprises a spiral of inside diameter 0.060″ and having about 20 double turns per inch. As described, the winding itself comprises the two wires 10 and 11, each consisting of six mil tungsten wire overwound with 1.5 mil wire 10′ (as shown in Fig. 3). We have found that at least about two of these wires 10 and 11 are necessary for each ampere of arc current. The dimensions herein given were designed for heating voltage supplies equal to 3.5 volts (3.5 amperes) during starting and 1.7 volts (1.8 amperes) during operation, corresponding to wattages of

about 12 and 3 watts respectively. The added wattage during starting aids in the rapid heating of the cathode. It is brought about by placing the cathode heating coils 24 in the secondary circuit of the power supply circuit to be described below. Here advantage may be taken of the effect of the resonant circuit 30—31 which causes a greater initial voltage to be induced in the heating coils. The end of wires 10 and 11 are clamped to metal shields 12 and 13 as shown at 14. In this manner they are electrically connected through the shields to stem press leads 15 and 16 embedded in stem press 17. The shields 12 and 13 and their function will be discussed in detail below.

In order to arrive at some approximate numerical value of the ratio of effective electron-emitting area to mass or heat capacity, we assume that the effective electron-emitting area constitutes the outer half of the circumference of the 1.5 mil wire and the uncovered portion of the 6 mil core wire. Thus, referring to Fig. 3 which shows an enlarged section of one of the wires 10 or 11, the area is indicated by the dotted lines, the uncovered portion of the 6 mil wire being taken as the projection *a*—*b* of the space separating the turns of the overwound smaller wire on the core. Actually, the area will vary with the amount of coating material picked up during the coating process and will also depend on how much of this material has been knocked of during operation. The approximation will, however, suffice for rough calculation.

Taking the density of tungsten to be 18.8 grams per cubic centimeter and the specific heat to be 0.034 calories per gram, the ratio of effective area in square centimeters to mass in grams is about 13, and the ratio of effective area in square centimeters to heat capacity in calories per gram about 380. Useful results can be obtained when the former of these two ratios is as low as 6, although we have set 13 as a practical lower limit. We could prefer the ratio to be as high as 17 to 20, or higher. Corresponding values of the area-heat capacity ratio are 176 for useful results and 500 to 590, or higher, for the preferred range. It will be understood of course that these ratios are calculated for tube voltages of the order of those specified herein, and that lower ratios may be used where the tube voltages are such that the rate of positive ion bombardment of the cathode when cold is less. Conversely high ratios will generally be required where the tube voltages are such that they tend to produce a greater rate of bombardment.

A second factor contributing to the low life and early blackening of lamps of this type was found to be a form of sputtering of loose material from the anodes, and their leads. The correction of this defect cannot be ignored if a lamp of reasonably long life is to be obtained. Under ordinary conditions, a quantity of loose and decomposable material exists on the anode and its leads. It may be foreign matter of the material of which the anode or the leads are constructed. It may even be composed of loose particles of insulating material used in manufacture. Under the influence of high velocity ions in the arc, particles of this loose material sputter to the wall of the envelope and thereby add to the blackening. The effect is particularly harmful where the anode voltage is applied before the cathode has been thoroughly heated, as is the case with the lamp of our invention. The reasons for this lies in the fact that a much higher voltage gradient will exist in the lamp before the cathode is heated and, therefore, the positive ions which bombard the anodes will have much higher energy. We find that this defect can be largely overcome by a preliminary ion bombardment of the anodes for the purpose of cleaning up the excess loose material on their surface. Ordinarily heating of the anodes will not accomplish this result since the mere process of heating does not impart sufficient energy to these particles to cause them to leave the anode surface. The high speed positive ions, on the other hand, apparently have sufficient energy to knock the loose material off the cathode. It is necessary, however, that during this preliminary bombardment the action be accomplished by ions having velocities substantially in excess of those which exist under the ordinary operating conditions of the lamp. This can be accomplished by a low pressure discharge between the two anodes. Thus, by reducing the argon pressure to the order to 0.2 to 0.7 mm. and passing a discharge of current strength in the approximate range of 5 to 30 milliamperes at 1700 volts between the anodes, a good cleanup can be effected within several minutes. At still lower pressures or higher currents the cleanup can be effected more rapidly. The blackening resulting from this treatment can be burned out of the tube during the subsequent exhaust operations by heating the tube in the presence of air or oxygen. This preliminary treatment greatly decreases the depreciation of the lamp.

The improved method whereby the cathodes are made relatively free of bombardment disintegration gives rise to still a third method of simplifying the auxiliary circuit. Hitherto it has been known that

low gaseous pressure was conducive to greater efficiency. However, a practical lower limit was placed upon the pressure by the extremely rapid disintegration of the cathodes at low pressures. In the past it has been found that a compromise between these two factors was best obtained at about 2.24 mm. The improved cathodes of our invention have lowered this practical limit still further and, as a result, we find that we are able to lower the starting voltage sufficiently to permit elimination of a high voltage starting winding. Thus, by lowering the argon pressure to the range of about 1.2 to 1.7 mm. we found that reliable starting could be obtained without the high voltage coils. The tube in this case had a length of 52 inches between electrodes and an internal diameter of 1.1 inches. However, as the ratio of tube length to tube diameter is decreased, the pressure at which this same starting voltage is effective to produce reliable starting decreases about in proportion to that ratio. While it is possible to operate below pressures of 0.7 mm., no gain of efficiency is obtained thereby. The omission of this winding will be readily apparent from a consideration of the drawing.

Returning now to a consideration of the operating circuit 8 of Fig. 1. In this circuit, the lamp is supplied from a source 18 of single phase alternating current which, for example, may be a 60-cycle, 110-volt lighting circuit, through the structure represented generally by numeral 8 and comprising a high reactive transformer and smoothing reactor. The core of the structure comprises two E-shaped members 19 and 20 reversely arranged with respect to each other and with corresponding legs spaced from each other to form magnetic gaps. In the drawing these gaps are shown for simplicity as air gaps, but as the apparatus is manufactured they comprise a suitable non-magnetic material against which the two members are clamped. Between the legs of the member 19 are magnetic shunts shown at 21 which increase the flux leakage to provide high leakage reactance.

On each of the outer legs of the core structure is a primary winding consisting of coils 22, a main secondary winding consisting of the coils 22 plus the coils 23 thereby constituting an auto transformer, and a separate auxiliary secondary winding comprising the coils 24 for heating the cathode 5. The ends of the primary are thus composed of the two coils 22 and are connected by the leads 25 and the switch 26 with the opposite sides of the source 18. The opposite ends of the main secondary composed of the two coils 22 and the two coils 23 connect with the two anodes 6—6 while the mid point thereof connects with the cathode. The latter connection includes the conductor 27 and the auxiliary secondary made up of the two coils 24, the purpose of which is to supply heating current to the lamp cathode. The coil 30 and condenser 31 comprise a resonant circuit shunted across the transformer output and hence across the anodes. They serve to further increase the voltage output with the result that greater voltage output is obtained without resorting to higher winding ratios at the same time they serve to increase the initial input to the cathode heating coils 24 as already stated.

As shown by the drawing the magnetic shunts 21 are arranged adjacent the upper ends of the primary coils and extend between the outer legs of the core structure and the middle leg 28 thereof. They are spaced from the legs by magnetic gaps which preferably comprise a suitable non-magnetic material. It will be seen that by this arrangement the amount of leakage of the primary flux is greatly increased since the shunts provide a relatively low reluctance leakage path. The net result is that the leakage reactance between the primary and the secondary is greatly increased. The middle leg 28 also provides a return path for the unidirectional component of the flux in each of the two outer legs during the operation of the lamp, such component being present by reason of the fact that the full wave rectifying action of the lamp renders the second current unidirectional. By reason of the middle leg, moreover, an exceptionally high reactance is obtained between the two halves or coils of the secondary winding because of the magnetic shunt effect thereof, whereby they are virtually isolated from each other.

The reflector 29 is provided for the purpose of facilitating the starting of the lamp. It is electrically connected to one of the anodes by the high impedance capacitor 32 (0.005 mf.), the effect of the connection being to lower the reflector potential with respect to one anode and increase its potential difference with respect to the other. The starting of the lamp is then aided by a capacitative discharge which tends to take place between the reflector and the latter of the two anodes. This starting operation is aided simultaneously by a low current cross discharge between the two anodes 6—6 around the baffle 7.

Returning now to Fig. 2 and a consideration of the shields 12 and 13 therein shown, it may be noted that ordinarily at pressures of 1.5 mm. or thereabouts, most

of the blackening that does occur in the cathode region, spreads out in the tube in a diffuse manner. In addition, at a short distance from the cathode a Faraday dark space forms and in the usual lamp of this type further discolouration deposits in a fairly well defined ring in this space. We have found that by placing the cylindrical shields 12 and 13 around the cathode, one for each end of the cathode coil, the Faraday dark space could be largely eliminated and the black ring on the tube thereby confined closely to the neighbourhood of the cathode. The diameter of the shield should not be small relative to the cathode, otherwise a secondary discharge will occur in the opening and reform the Faraday dark space. For example, with the cathode of the dimensions already described, the shields may each have the dimensions of about ½ inch in diameter and about 5/16 inch in length. The material of the shields is preferably nickel. They may be formed by bending a flat nickel strip into the form of a cylinder and spot welding the folded end tabs 30 to the leads and cathode coil.

The operation of the improved lighting unit hereinbefore described will be as follows: Upon application of voltage to the cathodes and anodes simultaneously, a heating current will pass through the cathodes to heat them to their rated operating temperature, while at the same time a starting discharge is initiated by the action of the shield as already described. Since the cathodes will heat substantially instantaneously they will not be damaged by the immediate application of the anode voltage to the tube, as has been the case with lamps of this general type in the past.

It will be understood that the above described circuit and lamp is illustrative of but one modification of our invention and that many variations in the circuit constants and in the form of the circuit and the lamp itself may occur to those skilled in the art to which our invention appertains. For example, it is not necessary that the lamp be of the full wave rectifying type as shown. It may be of the type having a single activated electrode at each end, each of these serving alternately as cathode and anode on each half cycle of alternating current. Further, since it is not essential that the lamp operates on alternating current only, it may be of the direct current type.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A low pressure gaseous electric discharge device comprising an envelope containing at least one pair of operating electrodes, at least one of which is activated, and a gaseous atmosphere, the activated electrode having a ratio of effective electron emitting surface in square centimeters to heat capacity in calories per gram not less than 176 to permit its being heated to electron emissive temperature before substantial deterioration by sputtering can occur, means for applying an electrical potential to the device whereby an operation potential is applied between the electrodes and whereby the activated electrode is simultaneously heated, the activated electrode being heated at a rate sufficient to cause it to reach electron emissive temperature within a time insufficient to permit substantial sputtering thereof by the discharge current.

2. A gaseous electric discharge device as claimed in Claim 1 in which the gaseous atmosphere comprises a metallic vapour and a starting gas and in which the activated electrode has a ratio of effective electron emitting area in square centimeters to heat capacity in calories per gram greater than about 380.

3. A gaseous electric discharge device as claimed in Claim 1 in which the initial rate of heating of the activated electrode by the heating means is substantially in excess of the rate of heating thereof during normal operation of the tube.

4. A gaseous electric discharge device as claimed in Claim 1 in which at least one of the electrodes comprises a plurality of turns of fine activated wires and has a shield concentrically surrounding it at a distance of about 4 times the diameter of the turns.

5. A gaseous electric discharge lamp according to Claim 1 of the full wave rectifying type comprising an envelope containing a gaseous atmosphere comprising a metallic vapour and a starting gas, a pair of anodes and an activated cathode, in which the means for establishing a discharge between the anodes and a cathode include a metallic shield adjacent to the envelope and electrically connected to one of the anodes.

6. A gaseous electric discharge device according to Claim 1 in which the cathode comprises an activated core member adapted to be heated to electron emissive temperature, and a pair of open ended cylindrical shields, each concentrically surrounding substantially completely, a different half of the core member at a distance of about 4 times the thickness thereof, each of the shields being electrically connected to the corresponding end of the core member.

7. The improved gaseous electric dis-

charge device and method of operating the same substantially as hereinbefore described.

Dated this 5th day of February, 1942.
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Agent for the Applicants.

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2nd Edition

[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 1.

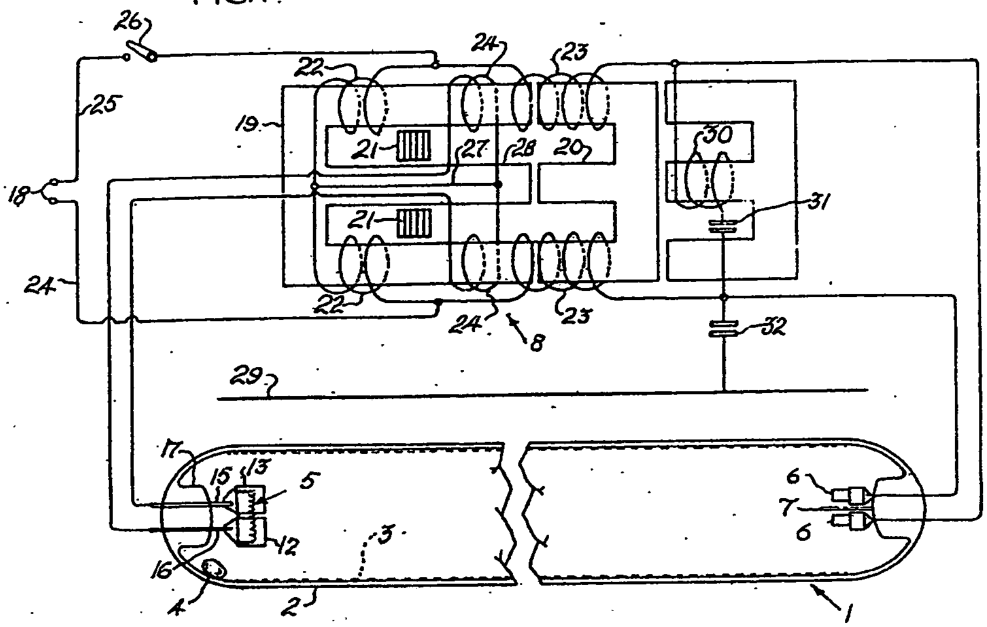

Fig. 2.

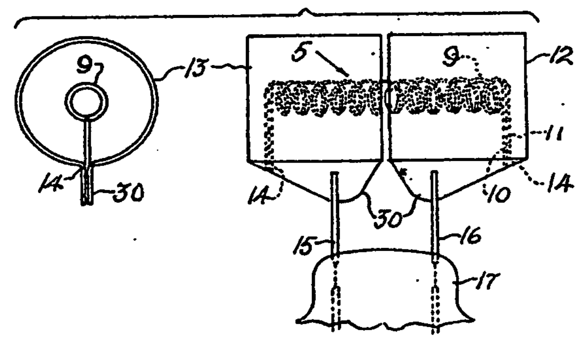

Fig 3